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that *Hamstead-Heath*, and *Finchley-Common*, and *Kennington Common*, may have been affected with it; yet it is notorious, that *London* was the Centre; the Place to which the Finger of GOD was pointed.

XXXIV

Some Considerations on the Causes of Earthquakes. By the Rev. Stephen Hales, D. D. and F. R. S.

Read April 5.
1750.

AS the late Earthquakes in *London*, and some other Parts of *England*, have roused the Attention of Mankind, to consider the Causes of them, both in a religious and natural View: And as in a religious View they have been considered by the Bishop of *London*, in his excellent Letter to the Clergy and People of *London*, which has been received with general Approbation: So I shall here give a short Account of what seems to me to be a probable natural Cause of them.

But I must first obviate an Objection of some serious well-meaning People, who are apt to be offended at any Attempts to give a natural Account of Earthquakes; which, but rarely happening in these more northern Parts, are apt to be looked upon as the more miraculous. But it ought to be considered, that the ordinary Course of Nature is as much carried on by the Divine Agency, as the extraordinary and miraculous Events. God sometimes changes the Order of Nature, with Design to chastise Man for his Disobedience

obedience and Follies, natural Evils being graciously designed by him as moral Goods: All Events are under his Direction, and fulfil his Will.

On the other hand, there are some who make light of Earthquakes, because they are capable of being accounted for by natural Causes. But the Hand of God is not to be overlooked in these things, under whose Government all natural Agents act; especially such rare and unusual Events as Earthquakes. God uses all Creatures to be the Instruments of his Will: Natural and moral Agents are all under his Direction. When he inflicts a Famine on a Nation, it is not the less the Hand of God; because we know the natural Causes of it, *viz.* great Drought, and unkindly Seasons: *Fire and Hail, Snow and Vapour, and stormy Wind, fulfil his Word*, Psal. cxlviii. 8. Infectious Air, pestilential Diseases, and Earthquakes, however occasioned by natural Causes, are under the Divine Influence. He not only orders and directs the Operations of Nature, but also influences the Actions of moral Agents, turning, as he pleases, the Hearts of the Governors of the Nations, so as frequently to chastize Mankind by that severe Scourge, and great Disgrace of human Nature, War. Earthquakes are not therefore slightly to be regarded, because we think we can give a probable natural Account of them; neither ought we, on that Account, to encourage ourselves to go carelessly on in wicked Courses. If national Judgments do not overtake us, yet it cannot be long before we shall come into the Punishment of our future State: *And tho' Sentence against an evil Work is not speedily executed, tho' a Sinner do Evil an hundred*

dred

dred times, and his Days be prolonged; yet surely I know it shall not be well with the Wicked. Eccles. viii. 11, 12, 13.

It may not be improper, on this Occasion, to mention another constant and uninterrupted Plague, in which, of late Years, we have been, and are like to continue Sufferers, in common with many other Nations. A Plague, of all others the greatest that ever befel unhappy Man; it being by far the most destructive, not only of the Lives, but also of the Morals, of Mankind; both a natural and a moral Evil: I mean fermented distilled Spirituous Liquors of all Denominations. Did God Almighty destroy as many by Earthquakes as are yearly destroyed by distilled Spirituous Liquors, which is probably about a Million of Persons in a Year all over the World; how great a Terror and Consternation would it cause every where! But, alas! with what Unconcernedness, with what Calmness, and even Complacency, is this enormous both natural and moral Evil received, and even fostered, among us; insomuch that it is now become, by a just Judgment, the Curse and the Punishment of the World, even the greatest that ever befel unhappy Man! Notwithstanding which, this enchanting *Siren* so bewitches and infatuates the Nations, that it spreads its baleful Influence far and wide, making yearly farther and farther Devastations, both of the Lives and Morals of Mankind, and even debasing the Breed of Man.

As to the Affair of Earthquakes, particularly that which happened at *London* the 8th of *March* last, about 20 Minutes before 6 in the Morning; I being then awake in Bed, on a Ground-floor, near the
Church

Church of *St. Martin's in the Fields*, very sensibly felt the Bed heave, and consequently the Earth must heave too. There was a hollow, obscure, rushing Noise in the House, which ended in a loud Explosion up in the Air, like that of a small Cannon: The whole Duration, from the Beginning to the End of the Earthquake, seemed to be about 4 Seconds of Time. The Soldiers who were upon Duty in *St. James's Park*, and others who were then up, saw a blackish Cloud, with considerable Lightning, just before the Earthquake began; it was also very calm Weather.

In the History of Earthquakes it is observed, that they generally begin in calm Weather, with a black Cloud. And when the Air is clear, just before an Earthquake, yet there are then often Signs of Plenty of inflammable sulphureous Matter in the Air; such as *Ignes Fatui* or *Jack-a-Lanterns*, and the Meteors called falling Stars.

Now, I have shewn many Years since, in the Appendix to my *Statical Essays*, Experiment 3. Page 280. the Effect that the Mixture of a pure and sulphureous Air have on each other; *viz.* by turning the Mouth downwards, into a Pan of Water, of a Glass Vessel of a Capacity sufficient to hold about two Quarts, with a Neck about twenty Inches long, and two Inches wide. Then, by putting under it, in a proper Glass Vessel, with a long narrow Neck, a Mixture of *Aqua fortis*, and powdered Pyrites, *viz.* the Stone with which Vitriol is made, there will be a brisk Ferment, which will fill the Glass with redish sulphureous Fumes; which, by generating more Air than they destroy, will cause the Water,
with

with which the whole Neck of the Glass Vessel was filled, to subside considerably. When the reddish sulphureous Air in the upper Part of the Glass is clear, by standing two or three Hours, if then the Mouth of the inverted Glass is lifted out of the Water, so as to let the Water in the Neck of the Glass fall out; which, supposing it to be a Pint, then an equal Quantity of fresh Air will rush in at the Mouth of the Neck of the Vessel, which must immediately be immersed in the Water: And upon the Mixture of the fresh Air with the then clear sulphureous Air, there will instantly arise a violent Agitation between the two Airs, and they will become, from transparent and clear, a reddish turbid Fume, of the Colour of those Vapours which were seen several Evenings before the late Earthquakes: During which Effervescence, a Quantity of Air, nearly equal to what fresh Air was let in, will be destroyed; which is evident by the rising up of the Water in the Neck of the Glass, almost as high as before. And if, after the Effervescence of the mixed Airs is over, and become clear again, fresh Air be admitted, as before, they will again grow reddish and turbid, and destroy the new admitted Air as before; and this after several repeated Admissions of fresh Air: But after every Readmission of fresh Air the Quantity destroyed will be less and less, till no more will be destroyed. And it is the same after standing several Weeks, provided, in the mean time, too much fresh Air had not been admitted. Now, I found the Sum total of the fresh Air thus destroyed to be nearly equal to the first Quantity of sulphureous Air in the inverted Glass.

Since we have in this Experiment a full Proof of the brisk Agitation and Effervescence which arises from the Mixture of fresh Air with Air that is impregnated with sulphureous Vapours, which arise from several mineral Substances, especially from the *Pyrites*, which abounds in many Parts of the Earth; may we not with good Reason conclude, that the irksome Heat, which we feel in what is called a close sultry Temperature of the Air, is occasioned by the intestine Motion between the Air and the sulphureous Vapours, which are exhaled from the Earth? Which Effervescence ceases, as soon as the Vapours are equably and uniformly mixed in the Air; as happens also in the Effervescences and Ferments of other Liquors. The common Observation therefore, that Lightning cools the Air, seems to be founded on good Reason; that being the utmost and last Effort of this Effervescence.

May we not hence also, with good Probability, conclude, that the first Kindling of Lightning is effected by the sudden Mixture of the pure serene Air above the Clouds, with the sulphureous Vapours, which are sometimes raised in Plenty, immediately below the Clouds? The most dreadful Thunders being usually when the Air is very black with Clouds; it rarely thundering without Clouds: Clouds serving, in this Case, like the above-mention'd inverted Glasses, as a Partition between the pure and sulphureous Airs: Which must therefore, upon their sudden Admixture thro' the Interstices of the Clouds, make (like the two Airs in the Glass) a more violent Effervescence, than if those Airs had, without the Intervention of the Clouds, more gradually

dually intermixed, by the constant more gradual Ascent of the warmer sulphureous Vapours from the Earth, and Descent of the cold serene Air from above. And tho' there was no luminous Flash of Light in the Glass, yet, when such sudden Effervescence arises, among a vast Quantity of such Vapours in the open Expanse of Air, it may, not improbably, acquire so rapid a Velocity, as to kindle the sulphureous Vapours, and thereby become luminous.

And since, from the Effects that Lightning is observed to have on the Lungs of Animals, which it often kills, by destroying the Air's Elasticity in them, as also from its bursting Windows outwards, by destroying the Air's Elasticity on the Outside of those Windows: Since, I say, it is hence probable, that the sulphureous Fumes do destroy a great Quantity of elastic Air; it should therefore cause great Commotions and Concussions in the Air, when the Air rushes into those evacuated Places; which it must necessarily do with great Velocity.

Dr. *Papin* has calculated the Velocity with which Air rushes into an exhausted Receiver, when driven by the whole Pressure of the Atmosphere, to be at the Rate of 1305 Feet in a Second of Time; which is at the Rate of 889 Miles in an Hour: Which is near 18 times a greater Velocity than that of the strongest Storms; which is estimated to be at the Rate of 50 Miles in an Hour *.

Hence

* *Phil. Transf.* n. 184, p. 195. Lowthorp's *Abridgment* of *Phil. Transf.* Vol. I. p. 586.

Hence, we see that an outrageous Hurricane may be caused, by destroying a small Proportion of the Elasticity of the Air of any Place, in respect to the Whole. No Wonder then that such violent Commotions of the Air should produce Hurricanes and Thunder-Showers; especially in the warmer Climates; where both the sulphureous and watry Vapours, being rais'd much higher, and in greater Plenty, cause more violent Effects.

Monsieur *de Buffon*, in his Natural History and Theory of the Earth, mentions black dark Clouds in the Air near the tempestuous *Cape of Good Hope*, and also in the Ocean of *Guiney*, which are called by the Sailors the *Ox's Eye*; which are often the Forerunners of terrible Storms and Hurricanes. Whence it is to be suspected, that they are large Collections of sulphureous Vapours; which, by destroying suddenly a great Quantity of the elastic Air, cause the ambient Air to rush with great Violence into that Vacuity, thereby producing Tempests and Hurricanes. And off the Coast of *Guiney* they have sometimes three or four of these Hurricanes in a Day; the Forerunners of which are these black sulphureous Clouds, with a serene clear Air, and calm Sea; which on a sudden turns tempestuous, on the Explosion of these sulphureous Clouds. And in *Jamaica* they never have an Earthquake when there is a Wind to disperse the sulphureous Vapours.

In the like manner we find, in the late Earthquakes at *London*, and in the Accounts of many other Earthquakes, that, before they happen, there is usually a calm Air, with a black sulphureous Cloud: Which Cloud would probably be dispersed
like

like a Fog, were there a Wind : Which Dispersion would prevent the Earthquake ; which is probably caus'd by the explosive Lightning of this sulphureous Cloud ; being both nearer the Earth than common Lightnings ; and also at a time when sulphureous Vapours are rising from the Earth in greater Quantity than usual ; which is often occasion'd by a long Series of hot and dry Weather. In which combined Circumstances, the ascending sulphureous Vapours in the Earth may probably take Fire, and thereby cause an Earth-Lightning ; which is at first kindled at the Surface, and not at great Depths, as has been thought : And the Explosion of this Lightning is the immediate Cause of an Earthquake.

It is in the like manner that those Meteors, which are called falling Stars, are supposed to be kindled into a Flame at the upper Part of a sulphureous Train, which is kindled downwards into a Flame, in the same manner as a fresh-blown-out Candle is instantly lighted from another Candle held over it at a Distance, in the sulphureous inflammable Smoke of it.

I am sensible that it may seem improbable, that the ascending sulphureous Vapours in the Earth should thus be kindled ; but, since they are continually ascending thro' the Pores of the Earth, more or less, for many good and useful Purposes, it is plain there is Room for them to pass. Besides, as *Monf. de Buffon* remarks, Naturalists have observed perpendicular and oblique Clefts, in all Kinds of Layers of Earth, not only among Rocks, but also among all Kinds of Earth, that have not been removed, as is observable wherever the Earth is open to any Depth. Now these

these Clefts are caused by the drying of the several horizontal Layers of the Earth; and will also be considerably the wider in long dry hot Seasons, which are usually the preparatory Forerunners of Earthquakes, and the Explosion of the sulphureous Vapours may probably widen them more.

It is very observable, in the Opinion of *Borelli*, and other Naturalists, that *Volcano's* begin first to kindle near the Surface or Top of the Mountains, and not in the Caverns in the lower Parts of the Mountains. *Monf. de Buffon* says, that Earthquakes are most frequent where there are *Volcano's*; sulphureous Matter abounding most there: But that, tho' they continue burning long, yet they are not very extensive. But that the other Sort of Earthquakes, which are not caused by a *Volcano*, extend often to a great Distance. These are much longer East and West, than broad North and South; and shake a Zone of Earth with different Degrees of Force in different Parts of their Course; *viz.* in proportion to the different Quantities of explosive sulphureous Matter in different Places. These kind of Earthquakes are observed to be progressive, and to take Time to extend to the great Distances sometimes of some Thousands of Miles. They are an instantaneous Explosion in every Place, near the Surface of the Earth; and therefore do not produce Mountains and Islands, as *Volcano's* sometimes do.

The Earthquake in *London*, *March* 8. was thought to move from Eastward to Westward. *M. Buffon* mentions an Earthquake at *Smyrna*, in the Year 1688. which moved from West to East; *viz.* because the first Kindling probably began on the Western Side; and in the Earthquake at *London* on

the Eastern Side. And accordingly it was observed, that the reddish Bows in the Air, which appeared several Days before that Earthquake, arose in the East, and proceeded Westward. It was observed, after the Earthquake at *Smyrna*, that the Castle-Walls, which run from East to West, were thrown down; but those from North to South stood; and that the Houses on Rocks stood better than those on the Earth.

M. *de Buffon* relates, that the Vibrations of the Earth, in Earthquakes, have commonly been from North to South; as appears by the Motion of the Lamps in Churches: Which makes it probable, that, tho' the Progress of the Earthquake at *Smyrna* was from West to East, yet the Vibrations of the Earth might be from North to South; and thereby occasion the Falling of the Castle-Walls, which run from East to West, but not those which run from North to South. A probable Argument, that, as the freest Passage, so the greatest Explosions were made in the Clefts of the Earth which run East and West; which would make the Vibrations North and South.

It was observed, that the Waters turned foul the Day before an Earthquake at *Bologna* in *Italy*: And I was informed, that the Water of some Wells in *London* turned foul at the time of the Earthquakes. Which was probably occasion'd by the Ascent of great Plenty of sulphureous Vapours thro' the Earth.

As to the hollow rumbling Noise, which is usually heard in Earthquakes, it seems not improbable, that it may be occasion'd by the great Agitation that the electrical æthereal Fluid is put into by so great a Shock of a large Mass of Earth. For, if the like Motion of
a small

a small revolving glass Globe can excite it to the Velocity of Lightning, and that with a Force sufficient to kill Animals, how much greater Agitation may it probably be excited to, by the explosive Force of an Earthquake!

The Explosion of a Cannon in *St. James's Park* is observed to electrify the Glass of the Windows of the *Treasury*. And what makes it still more probable, is, the Analogy that there is between them in other respects. For, as the electrical Flash rushes, with the Velocity of Lightning, along the most solid Bodies, as Iron, &c. and as I have seen it run only on the irregular Gilding of Leather; so such solid Bodies are observed to be the Conductors of aerial Lightning, which rends Oaks in Pieces, and has been known to run along and melt an iron Bell-Wire on two Sides of a Room, &c. And accordingly it was observed, in the great Earthquake in *Jamaica*, that the most tremendous Roaring was in the rocky Mountains. And in the late Earthquake of *March 8.* in *London*, the loudest Explosions were thought to be heard near such large Stone Buildings as Churches, with lofty Steeples and Spires.

I, who lay in *Duke's-Court*, near *St. Martin's Church*, and was awake all the Time of the Earthquake, plainly heard a loud Explosion up in the Air, like that of a small Cannon: Which made me conjecture, that the Noise was owing to the Rushing off, and sudden Expansion, of the electrical Fluid, at the Top of *St. Martin's Spire*; where all the electrical *Effluvia*, which ascended up along the larger Body of the Tower, being by Attraction strongly condensed, and accelerated at the Point of the Weathercock,

cock, as they rushed off, made so much the louder expansive Explosion.

XXXV.

The President's Report of the Account given him by Tho. Burrat, of Kensington, concerning the Earthquake on March 8. last past.

Read April 26. 1750. **O**N *Tuesday* the 24th of this present *April* 1750. Mr. *Thomas Burrat*, of *Kensington*, a Husbandman, and Bailiff to the Right Honourable *Henry Fox* Esq; of *Holland-House*, gave me the following Account :

That, being early about his Business in the Grounds about a Quarter of a Mile from the said House, on *Thursday* the 8th Day of *March* last, as he was going to tell his Sheep (which he does every Morning, and which were then lying down on a dry sloping Piece of Ground), he heard, as he thought, about a Quarter after Five a Clock, a Noise, much like Thunder at a Distance; which coming, to his Apprehension, from the North-West, continued some small time, growing louder as it came nearer him, and gave a Crack (so he expressed himself) over his Head; and then went off in the same manner it came on towards the South-East.

He said, that the Sky was, to his thinking, quite clear, and without any Cloud; and that he saw neither Lightning, nor any Appearance of Fire; but that, immediately after the Crack, he found the

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Ground